HIGH NITROGEN STAINLESS STEEL

This application claims the benefit of U.S. Provisional Application Ser. No. 60/086,761, filed May 27, 1998.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a high nitrogen stainless steel alloy powder, a high nitrogen content stainless steel alloy, a process for producing the high nitrogen stainless steel alloy powder and alloy, and articles prepared from the same.

2. Description of the Related Art

Early research on nitrogen-containing iron alloys was first reported at the Carnegie Institute in 1912. Later in the 1920's and 1930's, additional research was conducted in Europe, primarily in Germany, and to a lesser degree in the United States. Later in the 1970's, Armco developed a series of nitrogen containing steel alloys (the Nitronic® alloys), with specific alloys designed for either high strength, wear resistance or improved corrosion properties (Development of the Stainless Steels, Armco Inc., Middletown, Ohio (1983)). In the last 10 to 15 years there has been a dramatic increase in high nitrogen steel (HNS) research as evidenced by five international conferences on HNS, the latest being conducted in Helsinki and Stockholm. Despite the outstanding properties that a growing number of researchers have attributed to HNS, several factors have limited the huge potential of these alloys. These factors include: a) the formation of brittle, stable nitrides and intermetallics which precipitate during the slow cooling encountered during ingot casting, b) other casting defects such as macrosegregation which render these highly alloyed materials unworkable by conventional wrought processing techniques, and c) the difficulty in producing predictable nitrogen levels during both conventional and pressurized casting methods.

Prior research, particularly that which is described in G. O. Rhodes and J. J. Conway, J. Met. 48, 4 (1996), pp.28–31, and F. S. Biancaniello et al., in *Advanced Particulate Materials & Processes* 1997, MPIF (1997), pp 309–316, each incorporated herein by reference, has shown that many of the problems can be overcome by melting high nitrogen stainless steel (HNSS) under a nitrogen atmosphere, atomizing with N_2 gas and consolidating with a Hot Isostatic Press (HIP). The beneficial effects of nitrogen on the properties of HNSS include improved yield strength (YS), ultimate tensile strength (UTS), Charpy V-notch Impact Energy (CVN), corrosion and wear properties; all these properties improve with increasing nitrogen content. Nitrogen promotes the stability of the austenite phase (no martensite formation during cold work), and improves resistance to all types of corrosion. The benefits of nitrogen additions are reinforced by the microstructural refinements, enhanced chemical homogeneity and increased solubility of constituents which all convey from powder metallurgy rapid solidification process (RSP). RSP and HIP also provide the opportunity for near-net-shape fabrication of the alloys, minimizing machining time and scrap.

Typically a solution treatment and quenching are required to remove stable nitrides and sigma (σ) phases, as is reported in several articles including A. Rechsteiner et al., "New Methods for the Production of High Nitrogen Stainless Steels", *Innovation Stainless Steel*, Florence, Italy, October 1993, pp. 2107–2212; K. Orita et al., "Developments and Production of 18 Mn-18 Cr Nonmagnetic Retaining Ring with High Yield Strength", ISIJ Int., Vol. 30, No. 8, 1990, pp. 587–593; G. 0. Rhodes and J. J. Conway, J. Met. 48, 4 (1996), pp. 28–31; and F. S. Biancaniello et al., *Advanced Particulate Materials & Processes* 1997, MPIF (1997), pp 309–316. Also, see U.S. Pat. No. 5,841,046.

A few U.S. Patents have been issued related to nitrogen containing stainless steels.

U.S. Pat. No. 5,480,609 to Dupoiron et al., incorporated herein by reference, is directed to a steel containing 20 to 30% Cr, 25–32% Ni, 3–7% Mo, 0.05 to 5.4% Mn and 0.35–0.8% N, wherein the percentages are based on weight. As is typical for high nitrogen content steels, this patent discloses that the steel has corrosion resistance and structural stability. This patent further indicates that the nitrogen content should be limited to 0.8 to "avoid deteriorating the impact strength excessively by precipitating nitrides".

U.S. Pat. No. 5,841,046 to Rhodes et al., incorporated herein by reference, is directed to a stainless steel containing 20–29% Cr, 17–35% Ni, 3–10% Mo, 0.5 to 12% Mn and at least 0.7, preferably 0.8–1.1% N, wherein all of the percentages are based on weight. This patent further indicates a solution annealing process and water quenching process are needed to avoid formation of stable chromium nitride and sigma phase precipitates.

Other U.S. Patents such as U.S. Pat. No. 4,765,953 to Hagenfeldt et al, U.S. Pat. No. 4,853,185 to Rothman et al, and U.S. Pat. No. 5,141,705 to Stenvall et al., all teach nitrogen containing stainless steels. However, the compositions of these patents are outside the composition of the present invention.

In the state of the present art, the phrase "high nitrogen stainless steel" has an accepted meaning of a stainless steel having a nitrogen content of at least 0.3% by weight and more specifically at least about 0.5% by weight.

SUMMARY OF THE INVENTION

The present invention relates to a high nitrogen stainless steel alloy and alloy powder comprising chromium (Cr), molybdenum (Mo), manganese (Mn), nickel (Ni), nitrogen (N) and iron (Fe). The composition of the stainless steel alloy and alloy powder comprises about 27 to about 30% by weight Cr, about 1.5 to about 4.0% by weight Mo, Mn is present in the composition and is present in an amount up to 15% by weight, at least about 8% by weight Ni, and about 0.8 to about 0.97% by weight N with the balance being iron.

The present invention also relates to the formation of a stainless steel alloy which contains substantially a gamma (γ) microstructure. In addition, the high nitrogen stainless steel of the present invention has excellent physical properties in that the stainless steel is very strong, hard, ductile, and corrosion resistant. In addition, the stainless steel of the present invention has a high work hardening coefficient.

In the third aspect of the invention, the invention relates to a process for preparing the foregoing stainless steel alloy composition using a nitrogen gas atomization and consolidation process including, but not limited to, a hot isostatic pressing, hot extrusion or hot pressing .

In a final aspect of the present invention, the invention relates to an article prepared from stainless steel alloy. In particular, the stainless steel alloy of the present invention can be used to produce biomedical implants, especially orthopedic implants.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows the microstructure of a prior art stainless steel alloy.

FIG. **2** shows the microstructure of a stainless steel alloy of the present invention.